MONTHLY NOTICES

OF THE

ROYAL ASTRONOMICAL SOCIETY.

VOL. L. JANUARY 10, 1890. No. 3

W. H. M. CHRISTIE, M.A., F.R.S., President, in the Chair.

Albert Fowell Austin, Luton, Bedfordshire;
Algernon Sidney Bicknell, Staplefield Place, Crawley, Sussex;
Rev. George Burgess, The Woodlands, Urmston, Manchester;
Démétrius Eginitis, D. ès Sc., Observatoire, Paris;
George Richard Farncombe, M.A., 40 Belgrave Street, Birmingham;
Vernon Edwin Knocker, Castle Hill House, Dover;
Benjamin Noble, F.S.S., Gloucester House, Newcastle-on-Tyne;
Henry William Lloyd Tanner, M.A., 29 Clive Road, Penarth, South Wales;
R. Lethbridge Tapscott, Assoc. M.Inst.C.E., F.G.S., F.R. Met. Soc., 41 Parkfield Road, Liverpool;
William Grasett Thackeray, Royal Observatory, Greenwich,

were balloted for and duly elected Fellows of the Society.

The following candidates were proposed for election, the names of the proposers from personal knowledge being appended:—

The Rev. S. R. Craig, B.A., LL.B., F.S.S., The Rectory, Moville, Londonderry (proposed by W. J. Lancaster);
James Edward Keeler, B.A., Astronomer of the Lick Observatory (proposed by E. E. Barnard).

The Photographic Apparatus of the Great Equatorial of the Lick Observatory. By Edward S. Holden, LL.D., Director of the Lick Observatory, Foreign Associate.

The Lick Observatory has just received from the makers of the great telescope the compound slide-rest, which is to carry the negative plate of the Great Equatorial. It may be of interest to state the problem which this machine is destined to solve and to briefly describe its arrangements.

Accordingly I have asked Mr. Barnard to photograph our photographic appliances (see figure), which he has kindly done.

The problem which was early presented to us in the use of the photographic lens of the great telescope was this:—

The tube of the telescope (and very likely the declination axis) is subject to slight flexures, and all long exposures therefore produced short irregular lines instead of round dots for the star images. The focal length of the photographic lens is 47 feet 6·2 inches (aperture 33 inches), and one second of arc is 0·0028 inches on the plate ($1' = 0{\cdot}166$, $1^\circ = 9{\cdot}948$ inches).

So great a focal length makes a very slight *angular* displacement of the image readily visible on the plate as a considerable *linear* distortion.

Hence it was indispensable to provide some means of moving the plate by hand so as to keep the star images fairly round. The first experiments in photography were made by Mr. Burnham in August 1888, and the pictures of the Moon which have hitherto been made here are all by him. During September 1888 Professor Schaeberle constructed a compound slide-rest out of wood, by means of which experiments were made which fully showed that the method proposed would be entirely successful with an apparatus constructed out of metal. About the same time Mr. Common was kind enough to send me photographs of a very similar machine which he had adopted for his great reflector. (See *Monthly Notices*, R.A.S. vol. xlix. p. 297).

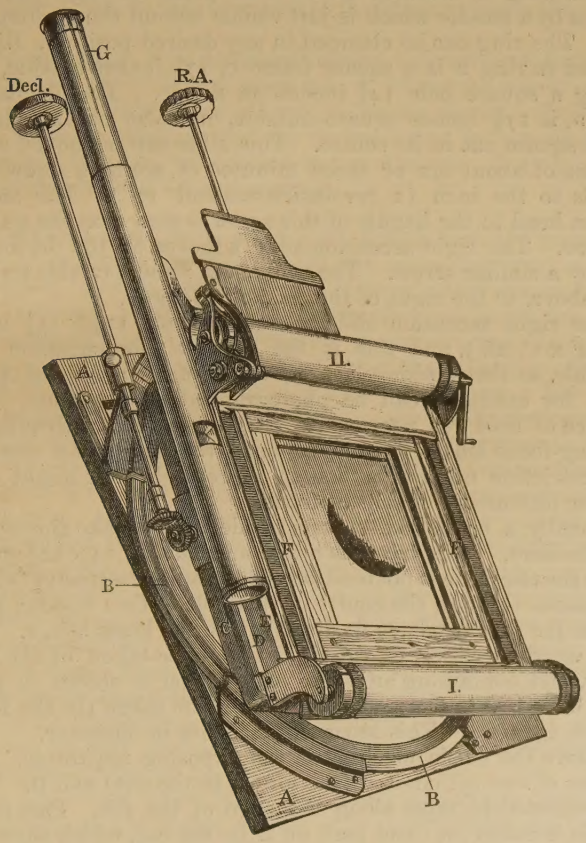
During January and February 1889 the final plan for our slide-rest was settled on, and it has been made by Messrs. Warner and Swasey in a highly satisfactory manner. In a few days it will be in place, and astronomical photography can be resumed here after a long and regrettable interval of lost time.

The general principle of the machine is as follows:—The negative plate is mounted on a slide-rest E, movable in right ascension; the slide-rest E together with the negative plate is movable in declination on a second slide-rest D. Attached to the right ascension slide-rest (E) is a guiding eyepiece G. The observer directs this eyepiece, which has a reticle plate of glass with wires as below,

upon some selected guiding star and then makes the exposure. As long as the star remains on the proper wire of the reticle the slides are left unchanged and the negative remains in its original place. As soon as the star leaves the wire the slides are moved by appropriate handles until the guiding star (and thus the negative) is brought back to its primitive position.

Such then is the general principle of the machine. In the apparatus for the Lick Observatory it was necessary to introduce one more complication, namely, to give the whole machine a rotation of some 40 degrees in its own plane. The focus of the photographic lens is 10 feet 4·2 inches nearer the object-glass than

the visual focus. Hence the photographic plate must be reached through a *port* cut in the side of the great tube. (This port is 23 by 12 inches.) The most convenient place for such a port is in the side of the tube nearest to the declination axis; but when the telescope was delivered to the astronomers I found that this port had been cut at random and without consideration in a different place, so that the negative plate when inserted would have its longest dimension inclined some 30 degrees to the parallel. Hence it was convenient to give the plate and the whole apparatus a motion of rotation of 30 degrees in its own plane.



Compound Slide-Rest, for carrying the Negative Plate of the 36-inch Equatorial.

A reference to the cut will make the following description plain:—The negative of the Moon is on an 8 × 10 plate. Hence the scale of the figure is easily determined. The machine was

delivered to us beautifully lackered. It has, however, been ruthlessly painted a dull black.

The lowest square frame of the apparatus I call plate A. This is $23 \times 24\frac{3}{4}$ inches, and in its centre is a square hole $19\frac{1}{2}$ inches on a side. When the apparatus is put in place this plate A is supported by four rods inside the telescope tube and parallel to its axis. A motion along these rods serves to focus the plate. The system of four rods has a thwart adjustment, so that the plate can be made normal to the incident ray. Above the plate A is a circular ring, B, about 23·7 inches outside and 21·5 inside diameter.

This ring is movable in its own plane through about 41 degrees by a handle which is just visible behind the guiding eyepiece. The ring can be clamped in any desired position. Rigidly fastened to ring B is a square frame C, $17\frac{1}{2}$ inches outside, containing a square hole $14\frac{1}{2}$ inches on a side. The declination slide, D, is $17\frac{1}{2}$ inches square outside, and also has a hole $14\frac{1}{2}$ inches square cut in its centre. This slide can be moved over a distance of about six or seven minutes of arc by a screw of 30 threads to the inch (1 revolution = about 10″). The smooth wooden head to the handle of this screw is seen next the guiding eyepiece. The right ascension slide E moves on the declination slide by a similar screw. The roughened handle of this screw is seen above, to the right of the guiding eyepiece.

The right ascension slide contains a hole $12\frac{1}{4} \times 14\frac{1}{4}$ inches ($1^\circ\ 14' \times 1^\circ\ 26'$), and this is the largest photographic field available, so that nothing like the whole of the nebula of *Andromeda*, for example, can be photographed at one time. This sacrifice of field was necessary. As the particular advantage of our long-focus lens is to produce negatives suitable for *measures*, this restriction of field is not so regrettable as it might be in another instrument of shorter focus.

Usually a brass box, F, rests inside of E to take the wooden plate-holders. This box has a free aperture of $14 \times 12\frac{1}{4}$ inches. When the telescope is not used for photography the cone of (visual) rays passes through the centre of this hole. Two wooden plate-holders for 11×14 plates fit directly into the brass box, F.

A wooden carrier, of the right size to be taken by the brass box, F, and containing an 8×10 plate-holder is shown in place, and I have laid in it a negative of the Moon taken (in the focus) August 13, 1888. This Moon is 5·2 inches in diameter.

Above the whole machine is the exposing apparatus. This consists of two cylinders, I (the lowest in the cut) and II. They are connected by tapes along the edge of the slit. Part of the curtain is rolled on I and part on II in the cut, which shows the disposition of things for a time-exposure. The lower roller, I, contains a strong spring. If the thumb-piece on the upper roller is touched, the curtain will fly down (in the cut) and cover the aperture. For an instantaneous exposure the upper roller must be rotated (by the small crank at its end) until the lower curtain covers the aperture. The slide of the plate-holder must then be drawn. At the proper time the thumb-piece must be

touched, when the curtain will fly down, carrying the open part of the curtain past the plate, and quickly covering the plate with that portion of the curtain shown rolled up on the upper roller.

The guiding eyepiece, G, is a positive eyepiece giving a power of about 500 diameters on the photographic objective. It can be moved bodily in the direction of its length, and clamped in any position. A beam from the objective is received on the prism (near its lower end in the cut) and brought to a focus on its glass reticle, previously described. The wires of this reticle are heavy enough to be seen without illumination. If any light is needed it can be had by means of luminous paint on the reticle itself.

For enlarging, it is necessary to slip a board and tube (not shown in the cut) into the brass box, F, where the negative now is. The brass tube takes all our enlarging lenses. These are about 2 inches aperture and 14 inches focus, giving direct enlargements near the *visual* focus of 7 or 8 times. A 4 × 5 double plate-holder is used for this purpose.

It will be seen from what goes before that the process of taking a satisfactory negative with the great telescope is not a simple one. Let us suppose that a plate of the Pleiades of two hours' exposure is required. The telescope must be set, the dome turned, the driving clock wound, set in motion, and the control put on. A high step-ladder must be moved so that the observer sitting on its top can look into the guiding eyepiece. The plate is to be inserted and the slide drawn; the whole photographic slide-rest must be rotated till the parallel of declination is in the same direction as the edge of the plate, and the curtain must be withdrawn for a time-exposure, after a suitable guiding-star has been chosen. The observer sits (helpless) on the top of his high ladder, while a second observer must keep the elevating floor at the right level, see that the telescope points fairly centrally through the slit, and watch for the proper times to move the high step-ladder, so as to allow the first observer as nearly a comfortable position as is practicable. All this must be done in a dark dome, where only the feeblest red light is permissible.

Exposures longer than two hours can only be made by interruptions for winding up the clock weight (of 600 lbs.), which only runs for that period. The difficulties are considerable, and the fatigue and labour are great.

On the other hand the advantages gained are immense. Photographs of the Moon, nebulæ, stars, and planets can be had on a scale of 1 minute of arc equal $\frac{1}{100}$ of an inch. These photographs can be quickly measured on our measuring-engine with an accuracy *at least* equal to the best heliometer measures. I think there is very little doubt that a distance of 3000″ can be measured with an accidental error of not much above $\frac{1}{10}$ of a second; and hence the photographic determination of parallax should be a comparatively easy matter, provided that constant errors are avoided by taking three or four plates each night. I

have as yet had only a limited opportunity to study our negatives.* I find, however, that an eyepiece of one inch equivalent focus can be used with advantage on our best Moon negatives. This corresponds to a magnifying power of 570 diameters. That is, it is practicable for an observer to sit in his study and to examine the lunar surface with a magnifying power of 570 diameters as often and as long as he pleases. Even more than this is true. Mr. Barnard has been kind enough to make positive enlargements on glass for me, which show the Moon twice as large as in the principal focus. An eyepiece of one inch equivalent focus is not too high to examine some features of these enlargements (and as they are *positives* they show the surface in its true light and colour). Thus it is practicable to see the lunar surface under excellent definition, and with a power of more than 1100 diameters, whenever one pleases and as long as one pleases.

I have no hesitation in saying that a study of our Moon negatives alone is capable of giving more information regarding the lunar surface than has been obtained by all the laborious years of observation by the most famous observers—Mädler, Lohrmann, Schmidt, and others now living.

It is simply necessary to study *two* sets of negatives, the second being necessary as a control on the first. Lest the above may seem to be too sanguine I will give one discovery I have lately made on our Moon negative of August 14, 1888.

It is well known that Mädler (and others) have mapped the walls of the Hyginus rill crossing the floor of the Hyginus crater. The observation is a delicate one and can only be made when the Sun is shining nearly in the direction of the preceding branch of this rill. Although this feature has often been mapped I think it has seldom been observed.

The walls inside the crater are hardly more than 1000 to 2100 yards apart, and their bright tops are not more than 200 to 220 yards wide. Yet I see these walls entirely well in the positive enlargement mentioned. From this single example it is possible to form a judgment of the results which a competent selenographer could draw from a suitably selected series of our Moon negatives. It is my intention to obtain such series as soon as practicable, and I shall offer a set, in the name of the Lick Observatory, to the Royal Astronomical Society in the hope that some "lonely and athletic student" may be willing to devote the two or three years necessary to their thorough and exhaustive study. It is not possible with the force at the disposition of the Lick Observatory to undertake more than the production of the materials for such a study. The study itself must, for the present at least, be left to others.

Lick Observatory, Mount Hamilton:
1889 *November* 23.

* See, however, a paper by Dr. Elkin in the *Astronomical Journal*, vol. ix. p. 35.

Observations of the Eclipse of Iapetus in the Shadows of the Globe, Crape Ring, and Bright Ring of Saturn, 1889 *November* 1.
By E. E. Barnard, M.A., Astronomer of the Lick Observatory.

Astronomers are, indeed, indebted to Mr. A. Marth for his keen foresight of some of the rarer phenomena of the planets and satellites that are out of the regular line of the almanac predictions.

A brilliantly clear sky and ordinarily good seeing here on the morning of November 2, permitted observations of a portion of the series of eclipses of *Iapetus* in the shadows of the globe and ring-system of *Saturn*, to which attention had been called by Mr. Marth in the June number of the *Monthly Notices*.

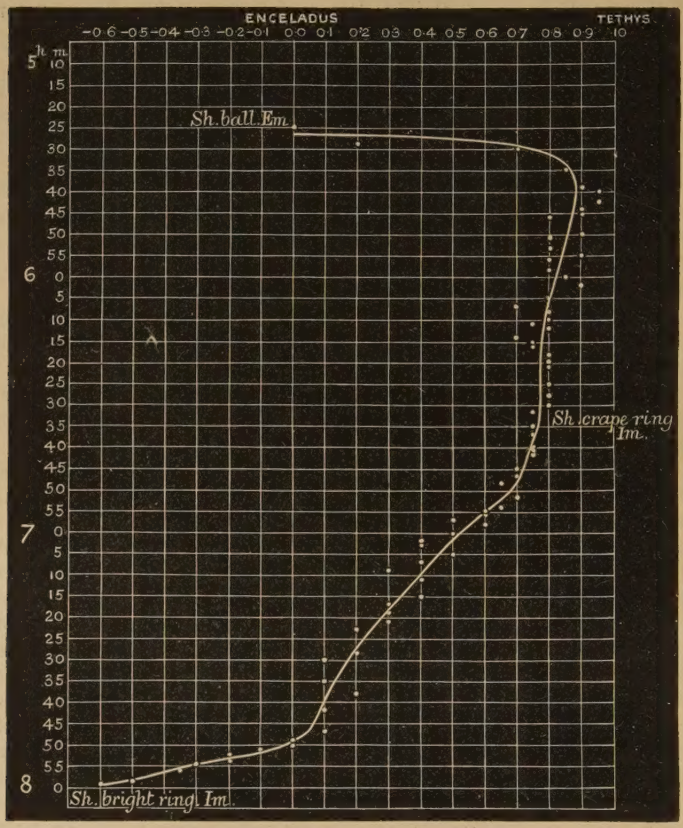
Professor Holden requested me to observe this phenomenon with the 12-inch equatorial, as it would be out of the reach of the great telescope.

As soon as *Saturn* became visible above the horizon I examined it, and made a sketch of the positions of the satellites for reference later.

At sidereal time, $4^h\ 30^m$, *Titan*, *Tethys*, *Enceladus*, *Dione*, and *Rhea* were visible, as given in the order of right ascension; the two last were following the planet. *Tethys* and *Enceladus* were quite near each other, close preceding the end of the ring. A sharp watch was kept at the approximate point of reappearance of *Iapetus* from the shadow of the globe. The time was recorded every few minutes, and a note made that the satellite was not visible. The last of these was at $5^h\ 17\frac{1}{2}^m$ sidereal time, when no trace of the satellite could be seen. At $5^h\ 25^m$ sidereal time the satellite was faintly caught, and for at least one half minute before this it was seen, but so faint and uncertain that it was not recorded. At the above time it was about as bright as *Enceladus*. Its light increased pretty rapidly. The point of appearance formed a right-angled triangle with *Tethys* and *Enceladus*, the right angle at *Tethys*, *Iapetus* being nearly due north of that satellite.

The idea at once occurred that it would be an excellent plan to test the effect of the shadow of the crape ring on the visibility of the satellite, by frequent comparisons of the light of *Iapetus* with that of *Tethys* and *Enceladus*. A series of comparisons was therefore begun. The standard of comparison was the difference of brightness between *Tethys* and *Enceladus*—this quantity being mentally divided into ten equal parts. Seventy-five such comparisons were made during the visibility of *Iapetus*. I have constructed a curve from these, using normals, of three estimates each, between comparisons 6 and 74, and through the points so found I have drawn the curve that best represents them (see figure, where the single comparisons are represented by dots, and where the curve is drawn by the aid of the normals). I have laid off time on the axis of x, and brightness on the axis of y.

The records that follow are in local sidereal time, as were the preceding.



Light Curve of the Eclipse of *Iapetus*, in the shadows of the Globe, Crape Ring, and Bright Ring of *Saturn*, 1889 Nov. 1.

If we examine the curve we shall see that the satellite quickly attained its maximum light at about $5^h\ 35^m$. After this there was seemingly a slow decrease until about $6^h\ 15^m$. From this time until $6^h\ 35^m$ the light of the satellite seemed to be constant or almost imperceptibly to diminish. At $6^h\ 35^m$ a steady and decided decrease commenced and continued until $7^h\ 50^m$, when the satellite began rapidly to disappear, the curve sinking quite sharply.

I do not understand the slight decrease of light so soon after the maximum had been reached, as it is evident from the curve that the satellite did not experience the effects of the crape ring until near $6^h\ 35^m$. If, however, we consider that the varia-

tion of light between $5^h\ 40^m$ and $6^h\ 15^m$ represents only 0·1 of a magnitude, it has less signification. (I am assuming with Prof. Pickering that the difference between *Enceladus* and *Tethys* was only one magnitude. See *Harvard College Observatory Annals*, vol. xi. p. 269. To me the difference in their light appeared somewhat greater than this.) I would rather refer this peculiarity to the fact that the seeing became better, and a fairer estimation could therefore be made of the relative light; if so, the curve should be flatter near $5^h\ 35^m$, to correspond with that near $6^h\ 25^m$.

This curve shows admirably how the semi-shadow of the crape ring affected the visibility of *Iapetus*. There was a regular decrease of the light of the satellite caused by this shadow, from $6^h\ 35^m$ to $7^h\ 45^m$, at which time *Iapetus* evidently struck the shadow of the inner bright ring into which it disappeared, being last seen at $7^h\ 59^m$.

The observations show that after passing through the sunlight shining between the ball and the rings, *Iapetus* entered the shadow of the crape ring. As it passed deeper into this the absorption of sunlight became more and more pronounced, until finally the satellite entered the shadow of the bright ring.

In a word, then, the crape ring is truly transparent—the sunlight sifting through it. The particles composing it cut off an appreciable quantity of sunlight. They cluster more thickly, or the crape ring is denser as it approaches the bright rings.

A magnifying power of 150 was used throughout on the 12-inch. The seeing ranged from 2 at the first observations of *Iapetus* up to 5 as dawn appeared.

Enceladus was last seen very faintly at $8^h\ 52^m$ sidereal time, and had certainly disappeared in the whitening sky at $8^h\ 53^m$.

Tethys disappeared at $8^h\ 57^m$; this was the last glimpse of it, the sky being quite white.

The following are the important instants, in Mount Hamilton mean time:—

	h	m	
Iapetus first certainly seen at	14	37·4,	November 1, 1889.
„ last „ „ at	17	11·0,	November 1, 1889.

The superb definition of the planet in the last part of the observations showed no abnormal appearance of the rings where the shadow of the ball crosses them, nor have I at any time seen a white spot on the rings at this or any other point.

In the diagram of the curve, the vertical column of figures represents the sidereal times of the individual estimations, while the horizontal column above gives the difference of light between *Enceladus* and *Tethys* in steps of one-tenth each.

The observations of the disappearance of the satellite (*Iapetus*) into the shadow of the bright ring show that, so far as the penetration of the solar rays is concerned, the bright ring is fully as opaque as the globe of *Saturn* itself.

TABLE OF LIGHT VARIATIONS OF IAPETUS.

November 1, 1889.

No.	Local Sid. Time. h m	Estimated Relative Light.	No.	Local Sid. Time. h m	Estimated Relative Light.
1	5 25·0	0·00	39	6 45·0	0·70
2	29·0	0·20	40	46·5	0·70
3	30·0	0·70	41	48·0	0·65 "decidedly fainter."
4	35·0	0·85	42	52·0	0·70
5	39·0	0·90	43	54·0	0·65
6	40·0	0·95	44	55·0	0·60
7	42·5	0·95	45	55·5	0·60
8	44·0	0·90	46	57·0	0·50
9	45·0	0·90	47	58·0	0·60
10	46·0	0·80	48	7 0·0	0·50
10½	50 0	0·90	49	2·0	0·40
11	51·0	0·80	50	3·0	0·40
12	53·0	0 80	51	5·0	0·50
13	55·0	0·90	52	7·0	0·40
14	56·0	0·80	53	9·0	0·30
15	58 0	0·80	54	11·0	0·40
16	6 0·0	0·85	55	15·0	0·40
17	2·0	0·90	56	17·0	0·30
18	5·0	0·80	57	19·0	0·30
19	7·0	0·70 "fainter."	58	21·0	0·30
20	8·0	0·80 "not fainter."	59	23·0	0·20
21	10 0	0·80	60	28·0	0·20
22	11 0	0·75 "fainter."	61	30·0	0·10
23	12·0	0·80	62	35·0	0·10
24	14·0	0·70 "fainter."	63	38·0	0·20
25	15·0	0·75	64	42·0	0·10
26	16·0	0·75	65	47·0	0·10
27	18·0	0·80	66	49·0	0·00
28	20·0	0·80	67	50·0	0·00 "perhaps slightly
29	21·0	0·80			less."
30	25·0	0·80	68	51·0	−0·10
31	27·5	0·80	69	52·5	−0·20
32	30·0	0·80	70	54·0	−0 20
33	32 0	0·75	71	54·5	−0·30
34	35·0	0·75	72	56·0	−0·35 "v. v. faint."
35	37·0	0·75	73	58·0	−0·50 "e. e. faint."
36	40·0	0·75	74	59·0	−0·60 "e. e. e. faint."
37	41·0	0·75	75	8 1·0	"no trace of it."
38	42·0	0·75	76	8 5·0	„ „

Mount Hamilton:
1889 *November* 22.

Spectroscopic Results for the Motions of Stars in the Line of Sight, obtained at the Royal Observatory, Greenwich, in the year 1889. *No. XIII.*

(*Communicated by the Astronomer Royal.*)

The results here given are in continuation of those printed in the *Monthly Notices*, vol. xxxvi. p. 318, vol. xxxvii. p. 32, vol. xxxviii. p. 493, vol. xli. p. 109, vol. xlii. p. 230, vol. xliii. p. 81, vol. xliv. p. 89, vol. xlv. p. 330, vol. xlvi. p. 126, vol. xlvii. p. 101, vol. xlviii. p. 116, and vol. xlix. p. 127. The observations were made with the "half-prism" spectroscope, one "half-prism," with a dispersion of about $18\frac{1}{2}°$ from A to H, being used throughout. A magnifying power of 14 was employed.

The cylindrical lens has always been used in front of the slit as in the observations made previously to 1881 and since 1882 March 14. The observations of the Sun, Moon, and planets have been made as a check on the general accuracy of the results.

The day specified in the first column is the civil day, and the hour is that of Greenwich civil time, commencing at Greenwich mean midnight, and reckoning from 0 to 24 hours.

The observations were made by Mr. Maunder throughout.

Motions of Stars in the Line of Sight in Miles per Second, observed with the Half-prism Spectroscope.

(+ denotes Recession; − Approach.)

Date. 1889.	h	No. of Meas.	Line	Earth's Motion in miles per sec.	Concluded Motion of Star. Measd.	Estimd.	Remarks.
				α Andromedæ.			
Jan. 1	20	2	F	+17·1	−50·4	−59·7	Spectrum bright and steady.
July 31	23	2	F	−14·4	−34·7	−23·1	Definition poor.
Sept. 6	23	2	F	− 7·7	−13·9	−15·0	Spectrum faint. Observed with difficulty.
16	23	2	F	− 5·2	−22·5	−24·5	Definition poor.
18	23	2	F	− 4·7	−22·0	−15·8	Star-line seen well.
25	23	2	F	− 2·8	−11·5	− 9·4	Definition bad.
Oct. 30	21	2	F	+ 7·1	−31·9	−36·0	Definition bad.
Nov. 25	21	2	F	+13·3	−49·0	−46·4	Definition poor.
				β Cassiopeiæ.			
July 31	22	2	F	−11·1	−27·4	−15·6	Definition poor.
Sept. 19	0	2	F	− 6·9	−48·9	−41·8	Star-line seen fairly well, but observing position very awkward.

Date. 1889.		No. of Meas.	Line.	Earth's Motion in miles per sec.	Concluded Motion of Star. Measd.	Estimd.	Remarks.
				γ Pegasi.			
Sept.	h 16 23	2	F	− 4·1	−19·1	−22·6	Definition poor.
	18 23	2	F	− 3·5	−36·2	−31·1	Spectrum faint, but steady.
Nov.	25 21	2	F	+15·4	−35·5	−36·9	Spectrum faint and tremulous.
				γ Cassiopeiæ.			
July	31 23	2	F	−11·7	+21·3	+19·7	Spectrum faint; definition poor.
Sept.	19 0	2	F	− 8·7	−21·3	−18·2	Spectrum bright and steady.
				β Arietis.			
Jan.	1 21	2	F	+17·6	−16·0	−17·6	Star-line very broad and diffused.
Sept.	18 23	2	F	−10·7	−31·4	−13·6	Spectrum bright and steady.
Nov.	25 22	2	F	+ 9·8	+20·1	+19·2	Definition poor.
				β Persei.			
Jan.	29 20	2	F	+16·9	−16·5	− 9·0	Spectrum very faint.
Feb.	15 20	4	F	+17·4	−15·5	−14·2	Spectrum faint, but steady.
Sept.	17 0	2	F	−14·6	−33·1	−35·7	Spectrum very faint.
	18 23	4	F	−14·3	+30·5	+33·2	Definition good.
	26 0	4	F	−13·3	−34·0	−29·2	Definition poor.
Nov.	25 21	4	F	+ 2·8	−22·3	−21·4	Definition poor.
				α Persei.			
Feb.	15 20	2	F	+16·2	−36·0	−43·3	Spectrum faint, but steady.
Sept.	17 0	2	F	−14·4	+12·6	+ 9·9	Spectrum bright and steady.
	18 23	2	F	−14·2	+ 8·6	+ 8·5	Definition fair.
	26 0	2	F	−13·4	+12·7	+13·4	Definition good.
Nov.	25 20	2	F	+ 0·9	+19·8	+25·6	Spectrum and star-line faint.
				Aldebaran.			
Jan.	1 22	1	F	+10·4	+32·7	+35·2	Observation very rough.
Feb.	4 20	2	F	+17·4	− 1·5	+10·2	Star-line seen with difficulty.
	15 21	4	F	+18·4	+30·7	+17·4	Star-line seen very well.
Mar.	5 21	2	b_1	+18·4	+51·1	+46·4	Spectrum *very* tremulous.
Sept.	19 0	2	F	−17·2	+39·6	+39·6	Spectrum rather faint.
Nov.	25 22	2	F	− 1·4	+57·9	+67·6	Spectrum bright and steady.
Dec.	20 21	2	F	+ 6·8	+79·8	+51·2	Observations very rough.

Date. 1889.	h	No. of Meas.	Line.	Earth's Motion in miles per sec.	Concluded Motion of Star. Measd.	Estimd.	Remarks.
				Capella.			
Feb.	15 21	4	F	+16·0	+ 7·8	+ 7·0	Star-line seen fairly well.
Mar.	5 21	2	b_1	+17·1	+ 3·2	+ 3·6	Spectrum *very* tremulous.
Sept.	17 0	2	F	−13·3	+31·3	+38·4	Definition poor.
	19 0	4	F	−16·7	+38·5	+40·4	Spectrum bright and steady.
	26 0	2	F	−16·5	+41·3	+40·8	Definition bad.
Nov.	25 22	2	F	− 4·9	+29·4	+33·9	Spectrum bright and steady.
				Rigel.			
Feb.	4 21	2	F	+14·1	+33·9	+41·0	Star-line seen fairly well.
	8 21	2	F	+14·6	+ 6·2	+11·6	Star-line seen well.
	15 22	2	F	+15·3	− 6·1	− 1·2	Spectrum very tremulous. Star-line seen with great difficulty.
Apr.	5 20	4	F	+13·4	+21·7	+14·7	Spectrum tremulous. Measures rough.
Nov.	25 23	2	F	− 3·5	+31·0	+33·3	Star-line seen well.
Dec.	20 22	2	F	+ 3·9	+33·8	+33·4	Spectrum very unsteady.
				γ Orionis.			
Feb.	4 21	4	F	+15·1	−10·2	− 4·8	Star-line seen fairly well.
	8 21	2	F	+15·8	− 9·6	− 5·1	Spectrum faint.
	15 22	2	F	+16·7	−31·2	−28·1	Star-line seen fairly well.
Nov.	25 23	2	F	− 4·8	−13·5	−17·6	Star-line seen fairly well.
Dec.	20 22	4	F	+ 3·1	+ 9·7	+ 6·8	Star-line seen fairly well.
				β Tauri.			
Feb.	4 21	2	F	+15·5	−14·9	− 2·6	Spectrum faint. Cloudy.
	8 21	2	F	+16·1	−25·7	−23·3	Star-line seen with difficulty.
	15 21	2	F	+17·2	−17·6	−14·0	Star-line seen well.
Sept.	26 0	2	F	−17·8	+16·9	+17·8	Definition fair.
Nov.	25 23	2	F	− 5·9	+40·0	+37·4	Star-line seen fairly well.
Dec.	20 22	2	F	+ 2·7	+29·5	+19·7	Star-line seen fairly well.
				δ Orionis.			
Apr.	5 21	2	F	+15·1	+11·2	+10·2	Spectrum faint. Measures rough.
Nov.	25 23	2	F	− 5·0	+11·0	+10·0	Star-line seen with difficulty.
Dec.	20 23	2	F	+ 2·6	+ 8·7	+ 2·4	Star-line seen fairly well.

Date. 1889.	h	No. of Meas.	Line.	Earth's Motion in miles per sec.	Concluded Motion of Star. Measd.	Estimd.	Remarks.
				ϵ Orionis.			
Nov. 25	23	2	F	− 5·3	+14·4	+17·7	Star-line seen fairly well.
Dec. 20	23	2	F	+ 2·2	+15·0	+12·7	Star-line seen fairly well.
				ζ Orionis.			
Nov. 26	0	4	F	− 5·6	+ 3·2	+ 5·6	Star-line seen fairly well.
Dec. 20	23	2	F	+ 1·9	+27·1	+13·0	Star-line seen fairly well.
				α Orionis.			
Mar. 5	22	4	b_4	+17·5	+ 2·6	+ 9·1	Star-line seen with great difficulty. Measures rough.
				β Aurigæ.			
Feb. 15	21	2	F	+15·0	− 3·5	+ 1·2	Spectrum bright and steady
Sept. 26	0	4	F	−17·0	− 0·6	+ 6·4	Definition poor.
Nov. 25	22	2	F	− 7·3	+31·9	+27·2	Spectrum fairly bright, but star-line faint.
				γ Geminorum.			
Feb. 15	23	4	F	+14·3	−75·0	−63·1	Spectrum faint but steady.
Dec. 20	23	2	F	− 2·7	−50·5	−33·7	Star-line seen very well.
				Sirius.			
Feb. 8	22	6	F	+ 8·9	−13·2	−13·1	Measures made with difficulty.
15	22	6	F	+10·2	−31·7	−28·4	Spectrum very unsteady.
Mar. 27	21	4	F	+14·1	−43·7	−49·5	Spectrum very unsteady.
Apr. 15	20	4	F	+13·7	−44·0	−45·5	Spectrum faint, and very unsteady. Measures very rough.
Nov. 26	0	6	F	− 9·1	+ 3·8	+ 7·5	Spectrum very unsteady.
Dec. 21	0	4	F	− 3·3	−51·8	−38·1	Spectrum very unsteady.
				Castor.			
Feb. 15	23	2	F	+11·6	+34·7	+23·1	Definition good.
Mar. 27	22	2	F	+17·8	−37·1	−43·2	Spectrum and star-line faint.
Apr. 25	22	2	F	+17·0	−13·4	− 7·0	Spectrum faint.
Dec. 21	0	2	F	− 6·2	+33·5	+23·6	Star-line seen well.
				Procyon.			
Feb. 8	22	2	F	+ 8·0	− 9·5	−11·6	Star-line faint.
15	23	4	F	+ 9·9	− 7·9	− 5·8	Star-line faint.
Mar. 27	22	2	F	+16·9	− 6·7	− 8·9	Spectrum fairly steady.
Apr. 15	21	1	F	+17·5	−43·0	−51·0	Observations interrupted by cloud.
Dec. 21	0	4	F	− 7·7	+ 6·7	+ 7·7	Star-line seen fairly well.

Date. 1889.	h	No. of Meas.	Line.	Earth's Motion in miles per sec.	Concluded Motion of Star. Measd.	Estimd.	Remarks.
				Pollux.			
Feb.	8 23	2	F	+ 9·0	−13·0	−16·1	Star-line seen with difficulty.
	15 23	2	F	+10·9	−52·7	−43·5	Star-line faint.
Mar.	5 22	2	b_1	+15·0	−43·2	−49·4	Spectrum very unsteady, but star-line sharp.
	27 22	2	F	+17·7	−53·4	−60·5	Star-line seen fairly well.
Dec.	21 0	2	F	− 7·2	−12·6	− 7·7	Star-line very faint.
				Regulus.			
Feb.	15 23	2	F	− 0·3	+25·2	+19·3	Spectrum seen well.
Mar.	27 22	2	F	+11·6	+13·3	+11·8	Observations made with difficulty.
Apr.	25 22	4	F	+16·7	+20·4	+20·7	Star-line seen well.
	30 22	2	F	+17·2	−24·2	−22·1	Spectrum bright but tremulous. Star-line faint, and seen with difficulty.
May	2 23	2	F	+17·4	+16·3	+20·7	Spectrum bright and fairly steady.
				γ Leonis.			
Mar.	5 23	2	b_1	+ 5·5	−30·7	−39·9	Spectrum bright but very tremulous.
	27 23	2	F	+11·5	−18·2	−25·5	Star-line seen with great difficulty. Measures rough.
Apr.	30 22	2	F	+17·0	+14·7	+17·8	Spectrum bright and fairly steady. Star-line faint.
				β Ursæ Majoris.			
May	2 22	4	F	+12·7	−25·1	−26·7	Spectrum bright and steady. Star-line seen well.
				α Ursæ Majoris.			
May	2 21	4	F	+11·7	−29·3	−27·8	Spectrum bright and steady. Star-line seen well.
				δ Leonis.			
May	3 23	2	F	+15·5	−63·1	−52·8	Spectrum rather faint.
				β Leonis.			
Mar.	27 23	2	F	+ 5·4	+ 8·4	+16·0	Spectrum bright and fairly steady. Star-line very broad, diffused, and difficult to bisect.
Apr.	30 22	4	F	+13·6	−25·0	−21·9	
May	2 23	4	F	+14·0	−71·1	−69·1	
				γ Ursæ Majoris.			
May	2 22	4	F	+11·8	+ 4·2	+ 4·3	Spectrum bright and steady.

Date. 1889.	h	No. of Meas.	Line.	Earth's Motion in miles per sec.	Concluded Motion of Star. Measd.	Estimd.	Remarks.
				δ Ursæ Majoris.			
May	2 22	4	F	+10·7	−15·5	−15·7	Spectrum bright and steady; star-line seen well.
				γ Virginis.			
Mar.	27 23	2	F	− 0·4	+22·6	+30·5	Measures rough and made with difficulty.
May	2 23	2	F	+10·1	−41·5	−38·0	Spectrum and star-line faint.
				ε Ursæ Majoris.			
May	2 23	4	F	+ 9·5	− 7·4	− 9·5	Spectrum bright and steady.
				α Canum Venaticorum.			
Mar.	27 23	2	F	+ 3·5	−55·1	−54·3	Spectrum faint but steady.
				Spica.			
Mar.	27 23	2	F	− 4·7	+31·2	+32·8	Spectrum bright but very tremulous.
Apr.	15 23	2	F	+ 1·2	+46·0	+35·6	Spectrum bright but tremulous.
	30 23	4	F	+ 5·7	− 9·8	−10·5	Star-line faint.
May	2 23	2	F	+ 6·3	− 8·7	− 6·3	Spectrum very tremulous.
				ζ Ursæ Majoris.			
Mar.	28 0	4	F	+ 4·0	−22·7	−32·4	Spectrum bright and steady; observing-position very awkward and measures rough.
May	3 0	4	F	+ 8·5	− 6·7	− 8·5	Spectrum bright and steady.
				η Ursæ Majoris.			
Mar.	28 0	2	F	+ 2·3	−62·6	−69·1	Spectrum bright and steady; observing-position very awkward and measures rough.
May	3 0	4	F	+ 7·7	−19·0	−23·8	Spectrum bright and steady.
				η Boötis.			
Mar.	5 23	2	b_1	− 8·8	+44·0	+44·2	Star-line seen with difficulty. Measures rough.
				Arcturus.			
Mar.	6 0	2	b	− 9·7	−49·3	−49·2	Spectrum bright but tremulous. Measures very accordant.
	22 0	2	F	− 5·5	−29·0	−20·9	Spectrum faint and tremulous.
	28 0	2	F	− 4·1	−31·9	−40·1	Spectrum bright but tremulous.

Date. 1889.	h	No. of Meas.	Line.	Earth's Motion in miles per sec.	Concluded Motion of Star. Measd.	Estimd.	Remarks.
Apr. 15	22	2	F	+ 0·9	−24·7	−31·0	Spectrum bright but tremulous.
30	23	2	F	+ 4·8	−25·1	−38·0	Star-line faint.
May 3	0	2	F	+ 5·3	−45·9	−47·4	Spectrum very bright but tremulous.
June 27	0	2	F	+14·6	−67·2	−61·5	Spectrum bright but *very* tremulous.
				γ Boötis.			
Apr. 30	23	2	F	+ 4·9	−69·1	−63·0	Spectrum rather faint, but steady.
				ϵ Boötis.			
Mar. 6	0	2	b_1	− 9·3	−13·8	−39·2	Star-line seen with difficulty. Measures rough.
				β Libræ.			
Apr. 30	23	2	F	− 2·2	−27·4	−26·8	Spectrum fairly bright, but tremulous.
				α Coronæ Borealis.			
Mar. 22	1	2	F	− 8·2	+ 8·8	+ 8·2	Definition poor. Measures rough.
Apr. 30	23	2	F	0·0	+27·6	+21·5	Spectrum bright, and fairly steady.
June 27	0	4	F	+10·4	−13·1	− 6·9	Spectrum very tremulous. Measures very rough.
July 15	23	4	F	+12·2	+24·9	+29·2	Spectrum bright, but tremulous.
				β Serpentis.			
Apr. 30	23	2	F	− 2·0	−40·6	−39·5	Spectrum faint, but fairly steady.
				α Ophiuchi.			
Apr. 30	23	2	F	− 9·4	+56·1	+59·2	Spectrum bright, and fairly steady.
June 27	0	2	F	+ 3·6	−33·3	−38·8	Definition poor.
July 15	23	2	F	+ 7·8	−36·1	−30·0	Spectrum bright, but tremulous.
19	23	4	F	+ 8·6	−34·8	−36·4	Spectrum fairly bright and steady.
				Vega.			
Apr. 30	23	4	F	− 7·6	−22·6	−20·6	Spectrum very bright and steady.
June 27	1	2	F	− 1·2	− 3·3	− 8·2	Spectrum very tremulous.
July 16	0	4	F	+ 1·4	−22·0	−24·6	Definition poor.
19	23	4	F	+ 2·0	−22·4	−27·0	Spectrum very bright.
Sept. 6	21	2	F	+ 7·5	−59·7	−54·4	Definition fair.
13	21	2	F	+ 8·0	−47·0	−41·9	Definition poor.
16	20	2	F	+ 0·8	−35·0	−38·9	Star-line seen well.
18	21	2	F	+ 8·2	−56·2	−49·8	Definition fair.

Date. 1889.	h	No. of Meas.	Line.	Earth's Motion in miles per sec.	Concluded Motion of Star. Measd.	Estimd.	Remarks.
				γ Lyræ.			
Sept. 18	21	2	F	+ 9·5	−82·1	−63·9	Spectrum very faint. Measures rough, and made with great difficulty.
				ζ Aquilæ.			
July 15	23	4	F	+ 1·3	−22·6	−23·6	Star-line seen fairly well.
19	23	2	F	+ 2·3	−48·2	−46·8	Spectrum faint. Star-line difficult to bisect.
Sept. 18	21	2	F	+13·6	−25·6	−27·1	Spectrum very faint. Measures rough, and made with great difficulty.
				δ Aquilæ.			
July 19	23	2	F	+ 1·5	−34·3	−29·3	Spectrum very faint. Measures rough.
				δ Cygni.			
Sept. 18	21	2	F	+ 5·2	+ 9·4	+ 7·6	Spectrum very faint. Measures rough.
				Altair.			
June 27	0	2	F	− 6·5	−44·8	−40·4	Observations interrupted by cloud.
July 16	0	4	F	− 1·8	−26·0	−24·0	Definition poor.
20	0	2	F	− 0·8	−50·0	−49·3	Spectrum bright and steady.
Sept. 6	22	2	F	+11·0	−41·0	−40·8	Definition fair.
13	21	2	F	+12·3	−34·0	−35·5	Definition poor.
16	21	4	F	+12·8	−34·6	−39·9	Star-line seen fairly well.
18	22	4	F	+13·2	−37·1	−39·1	Definition fair.
25	22	2	F	+14·2	−39·1	−41·0	Spectrum faint and tremulous.
				α Cygni.			
June 27	1	2	F	− 7·6	−43·6	−34·6	Definition good.
July 16	0	2	F	− 5·8	−51·5	−49·8	Star-line seen fairly well.
20	0	2	F	− 5·3	−39·0	−41·1	Observing-position very awkward.
31	22	2	F	− 3·8	−50·6	−27·4	Definition poor.
Sept. 6	23	2	F	+ 1·7	−27·6	−35·8	Star-line faint and seen with difficulty.
13	22	2	F	+ 2·7	−26·2	−32·8	Star-line faint and seen with difficulty.
16	21	2	F	+ 3·2	−64·1	−61·1	Observing-position awkward.
18	22	2	F	+ 3·5	−32·4	−32·3	Definition fair.
25	23	2	F	+ 4·5	−59·5	−50·1	Definition good.
				α Cephei.			
July 20	0	2	F	− 6·2	−78·4	−67·9	Observing-position very awkward.
31	22	2	F	− 5·7	−44·9	−23·3	Definition poor.

Date. 1889.		No. of Meas.	Line.	Earth's Motion in miles per sec.	Concluded Motion of Star. Measd.	Estimd.	Remarks.
	h						
Sept.	16 22	2	F	− 1·9	−30·9	−34·7	Observing-position very awkward. Measures rough.
	25 23	2	F	− 0·9	−53·6	−42·9	Star-line seen with great difficulty. Measures rough.
				α Pegasi.			
Sept.	13 22	1	F	− 0·2	−56·3	−46·1	Observations interrupted by cloud.
	16 22	2	F	+ 0·7	−30·9	−31·2	Star-line seen fairly well.
	18 22	2	F	+ 1·3	−53·0	−50·0	Spectrum faint. Measures rough and made with difficulty.
				Venus.			
Feb.	4 19	2	F	...	+20·1	+18·1	Calculated motion −7·8 miles per second.
	15 21	2	F	...	−14·9	−11·4	Calculated motion −8·0 miles per second.
				Moon.			
Feb.	4 20	5	F	...	− 2·0	...	The coincidence of the two spectra appeared perfect.
	15 23	5	F	...	+ 2·7	...	Measures made with pointer.
	16 0	5	F	...	+ 2·8	...	Measures made with spider-line.
Apr.	5 21	5	F	...	+ 3·0	...	
	15 21	8	F	. .	− 1·5	...	
July	16 0	5	F	...	+ 0·3	...	
Sept.	6 22	5	F	...	− 1·6	...	
	17 1	5	F	...	+ 1·6	...	
Dec.	3 21	5	F	...	+ 2·3	...	
				Sun.			
May	3 12	5	F	...	− 1·6	...	The coincidence of the two spectra appeared perfect.
				Sky.			
Feb.	9 12	5	F	...	+ 1·5	...	The coincidence of the two spectra appeared perfect.
Mar.	28 12	5	F	...	+ 1·3	...	
Aug.	1 11	5	F	...	+ 1·4	...	
Sept.	26 12	5	F	...	− 0·1	...	

Ring of Saturn.

Relative displacement of the preceding and following ansæ of Ring B immediately within the Cassinian division.

	h			*p*−*f* ansa.	
Mar.	5 22	5	b_1	+37·0	Spectrum very faint; lines seen with great difficulty. Observations rough. Computed relative motion, +19·4 miles per second.

Observations of Occultations of Stars by the Moon and of Phenomena of Jupiter's Satellites, made at the Royal Observatory, Greenwich, in the year 1889.

(*Communicated by the Astronomer Royal.*)

Occultations of Stars by the Moon.

Day.		Phenomenon.	Telescope.	Power.	Moon's Limb.	Mean Solar Time of Observation. h m s	Observer.
1889, Feb.	9	Disapp. *i* Tauri	Altaz.	100	Dark	6 46 18·15	A. D.
	12	,, 63 Geminorum	Altaz.	100	,,	7 40 47·33	H. T.
	12	,, 63 Geminorum	E. Equat.	140	,,	7 40 47·49	H.
Sept.	16 (*a*)	,, ζ Tauri	Lassell Refl.	280	Bright	12 53 41·49	H. T.
	16 (*b*)	,, ζ Tauri	Altaz.	100	,,	12 53 41·15	L.
	16	Reapp. ζ Tauri	Lassell Refl.	280	Dark	13 36 55·29	H. T.
	16	,, ζ Tauri	Altaz.	100	,,	13 36 55·96	L.
Oct.	5	Disapp. 56 Aquarii	Altaz.	100	,,	8 39 47·40	T.
	29	,, Piazzi xix. 22	Altaz.	100	,,	6 30 57·95	W. R.
Dec.	31	,, 85 Ceti	E. Equat.	200	,,	5 4 58·36	C.
	31	,, 85 Ceti	Altaz.	100	,,	5 4 57·86	H.

Notes.

(*a*) No projection. Disappeared instantaneously at bright limb.

(*b*) Star touched the Moon's limb 5 seconds before time of observation, was wholly inside the limb at $12^h\ 53^m\ 40^s$; it appeared as a brilliant spot on the Moon, and disappeared suddenly at time given above.

For the occultation of *Jupiter* on August 7 and of Satellites II. and IV., see vol. l. p. 36.

Phenomena of Jupiter's Satellites.

Day.	Satellite.	Phenomenon.	Telescope.	Power.	Mean Solar Time of Observation.	Mean Solar Time of N.A.	Observer.
					h m s	h m s	
1889 Apr. 22 (*a*)	III.	Ecl. D. Last seen	E. Equat.	140	14 5 25	14 4 35	J. P.
May 21 (*b*)	I.	Occ. R. Last contact	Lassell Refl.	280	13 22 0	13 20 0	H. T.
29 (*c*)	I.	Tr. Egr. First contact	Altaz.	100	12 11 34	12 13 0	A. D.
29	I.	Last contact	,,	,,	12 14 53		,,
31 (*d*)	II.	Occ. R. First seen	Lassell Refl.	280	13 56 7	13 56 0	H.
31	II.	Full brightness	,,	,,	14 4 47		,,
June 4	I.	Ecl. D. Began to fade	,,	,,	14 5 40	14 7 23	,,
4	I.	Last seen	,,	,,	14 7 50		,,
July 6	I.	Occ. D. First contact	Corbett Refr.	110	10 16 8		A. D.
6	I.	Bisection	,,	,,	10 19 22		,,
6	I.	Last seen	,,	,,	10 22 28		,,
6 (*e*)	I.	First contact	Lassell Refl.	280	10 17 45	10 22 0	L.
6	I.	Bisection	,,	,,	10 19 55		,,
6	I.	Last seen	,,	,,	10 22 30		,,
15	I.	Ecl. R. First seen	Altaz.	100	9 18 6	9 17 28	T.

Day.	Satellite.	Phenomenon.	Telescope.	Power.	Mean Solar Time of Observation.	Mean Solar Time of N.A.	Observer.
					h m s	h m s	
1889 July 18	II.	Tr. Egr. First contact	Lassell Refl.	280	11 34 9		A. D.
18	II.	Bisection	,,	,,	11 35 39	11 37 0	,,
18	II.	Last contact	,,	,,	11 38 13		,,
Aug. 6	I.	Tr. Egr. First contact	Altaz.	100	11 13 54	11 16 0	T.
6	I.	Last contact	,,	,,	11 17 39		,,
15	III.	Ecl. R. First seen	Lassell Refl.	280	8 34 35		H. T.
15 (*f*)	III.	First seen	E. Equat.	200	8 35 27		C.
15	III.	Full brightness	,,	,,	8 37 57	8 37 16	,,
15 (*g*)	III.	First seen	Altaz.	100	8 36 30		J. P.
15	III.	Full brightness	,,	,,	8 38 37		,,
28	II.	Ecl. R. First seen	,,	,,	9 18 30	9 17 47	L.
28	II.	Full brightness	,,	,,	9 19 38		,,
29	III.	Occ. D. First contact	,,	,,	8 55 4	8 46 0	S. D.
29	III.	Last seen	,,	,,	8 57 54		,,
Sept. 6	I.	Occ. D. First contact	Lassell Refl.	280	8 2 44		A. D.
6	I.	Bisection	,,	,,	8 5 1	8 8 0	,,
6	I.	Last seen	,,	,,	8 7 23		,,
12 (*h*)	IV.	Tr. Egr. Last contact	E. Equat.	210	7 26 31	7 38 0	A. D.

Day.	Satellite.	Phenomenon.	Telescope.	Power.	Mean Solar Time of Observation.	Mean Solar Time of N.A.	Observer.
					h m s	h m s	
1889 Oct. 7 (*i*)	I.	Tr. Ing. Bisection	E. Equat.	140	7 25 20		H.
7	I.	Last contact	,,	,,	7 28 0		,,
7 (*k*)	I.	First contact	Altaz.	100	7 21 18	7 29 0	A. P.
7	I.	Bisection	,,	,,	7 24 8		,,
7	I.	Last contact	,,	,,	7 27 17		,,

Notes.

(*a*) *Jupiter* diffused. (*b*) Definition too poor to permit observation of "First Seen." The satellite was well clear of *Jupiter* at $13^h\ 23^m\ 30^s$.

(*c*) *Jupiter* very tremulous and ill-defined. Observation uncertain.

(*d*) Observation *very* uncertain; limb of *Jupiter* boiling.

(*e*) Satellite very faint; cloudy.

(*f*) Clouds passing.

(*g*) Suspected at $8^h\ 35^m\ 53^s$.

(*h*) Satellite very faint; not noticed until near last contact.

(*i*) Image not good.

(*k*) Satellite faint; *Jupiter* diffused.

The clear aperture of the mirror of the Lassell Reflector is 24 inches, of the object-glass of the E. Equatorial 6·7 inches, of the Corbett Refractor $6\frac{1}{2}$ inches, and of the Altazimuth $3\frac{3}{4}$ inches.

The initials H. T., C., A. D., T., L., H., J. P., A. P., S. D., and W. R., are those of Mr. Turner, Mr. Criswick, Mr. Downing, Mr. Thackeray, Mr. Lewis, Mr. Hollis, Mr. Power, Mr. A. Pead, Mr. Dolman, and Mr. Russell respectively.

Ephemeris of the Satellites of Uranus, 1890. By A. Marth.

Greenwich Noon. 1890.		*Ariel.* P	a_1	b_1	u_1-U	*Umbriel.* a_2	b_2	u_2-U
Feb.	26	281°·31	14″·88	+9″·52	101°·55	20″·74	+13″·27	223°·16
Mar.	8	·39	14·98	9·53	89·94	20·87	13·28	11·85
	18	·49	15·06	9·52	78·29	20·99	13·26	160·51
	28	·60	15·12	9·48	66·61	21·07	13·21	309·15
Apr.	7	·72	15·16	9·42	54·91	21·11	13·12	97·76
	17	·84	15·16	9·33	43·19	21·12	13·00	246·37
	27	281·95	15·15	9·23	31·44	21·10	12·86	34·96
May	7	282·06	15·10	+9·12	19·67	21·04	+12·71	183·54
	17	·15	15·03	9·01	7·89	20·95	12·55	332·12
	27	·23	14·95	8·89	356·10	20·82	12·39	120·70
June	6	·29	14·84	8·78	344·31	20·68	12·24	269·28
	16	·33	14·73	8·68	332·52	20·52	12·09	57·87
	26	·34	14·60	8·59	320·74	20·34	11·97	206·47
July	6	·33	14·47	8·52	308·97	20·16	11·86	355·09
	16	282·31	14·34	+8·46	297·22	19·98	+11·78	143·72

		Titania. a_3	b_3	u_3-U	*Oberon.* a_4	b_4	u_4-U	U	B
Feb.	26	34″·01	+21″·76	138°·97	45″·48	+29″·10	2°·62	359°·72	+39°·78
Mar.	8	34·24	21·78	192·45	45·79	29·14	269·97	359·78	39·51
	18	34·42	21·75	245·91	46·03	29·09	177·30	359·86	39·19
	28	34·56	21·66	299·35	46·21	28·96	84·62	359·94	38·82
Apr.	7	34·63	21·51	352·78	46·32	28·77	351·93	0·03	38·41
	17	34·65	21·32	46·21	46·34	28·52	259·24	0·12	37·99
	27	34·61	21·10	99·63	46·28	28·22	166·54	0·21	37·57
May	7	34·51	+20·85	153·05	46·15	+27·88	73·85	0·29	+37·17
	17	34·36	20·59	206·47	45·94	27·53	341·16	0·36	36·82
	27	34·16	20·32	259·90	45·68	27·18	248·48	0·42	36·52
June	6	33·92	20·06	313·34	45·37	26·84	155·81	0·46	36·28
	16	33·65	19·83	6·79	45·00	26·53	63·16	0·48	36·12
	26	33·36	19·63	60·26	44·62	26·25	330·52	0·49	36·04
July	6	33·07	19·46	113·75	44·22	26·02	237·90	0·48	36·04
	16	32·77	+19·32	167·25	43·82	+25·84	145·30	0·45	+36·13

The values of P, a, b, $u-U$ are to be interpolated for the times for which the apparent positions of the satellites are

required (the degrees of the differences of successive values of $u-U$ being in the case of *Ar.* 1428°, *Um.* 868°, *Tit.* 413°, *Ob.* 267°), and the position-angles p and distances s are then found by means of the formulæ—

$$s \sin (p-P) = a \sin (u-U)$$
$$s \cos (p-P) = b \cos (u-U).$$

The satellites will be at their greatest elongations (N in position-angle P+90°, S in position P−90°) and at their conjunctions with the planet's centre (superior conjunction in position-angle P, inferior conjunction in position P−180°) at the following hours, Greenwich mean time:—

Ariel.

1890.	N. Elong. h	S. Elong. d h		N. Elong. h	S. Elong. d h		N. Elong. h	S. Elong. d h
Mar. 2	23·0	4 5·3	Apr. 9	18·4	11 0·6	May 17	13·8	18 20·0
5	11·5	6 17·8	12	6·9	13 13·1	20	2·3	21 8·5
8	0·0	9 6·3	14	19·4	16 1·6	22	14·8	23 21·0
10	12·5	11 18·7	17	7·9	18 14·1	25	3·3	26 9·5
13	1·0	14 7·2	19	20·4	21 2·6	27	15·8	28 22·0
15	13·5	16 19·7	22	8·9	23 15·1	30	4·3	31 10·5
18	2·0	19 8·2	24	21·3	26 3·6	June 1	16·8	2 23·0
20	14·5	21 20·7	27	9·8	28 16·1	4	5·3	5 11·5
23	2·9	24 9·2	29	22·3	M. 1 4·6	6	17·8	8 0·0
25	15·4	26 21·7	May 2	10·8	3 17·1	9	6·3	10 12·5
28	3·9	29 10·2	4	23·3	6 5·6	11	18·7	13 1·0
30	16·4	31 22·7	7	11·8	8 18·1	14	7·2	15 13·5
Apr. 2	4·9	3 11·2	10	0·3	11 6·6	16	19·7	18 2·0
4	17·4	5 23·6	12	12·8	13 19·1	19	8·2	20 14·5
7	5·9	8 12·1	15	1·3	16 7·6	21	20·7	23 3·0

Umbriel.

	h	d h		h	d h		h	d h
Mar. 4	18·1	6 19·9	Apr. 11	1·3	13 3·1	May 18	8·6	20 10·3
8	21·6	10 23·3	15	4·8	17 6·5	22	12·0	24 13·8
13	1·1	15 2·8	19	8·3	21 10·0	26	15·5	28 17·3
17	4·5	19 6·3	23	11·7	25 13·5	30	19·0	J. 1 20·7
21	8·0	23 9·7	27	15·2	29 16·9	June 3	22·5	6 0·2
25	11·5	27 13·2	May 1	18·7	3 20·4	8	1·9	10 3·7
29	14·9	31 16·7	5	22·2	7 23·9	12	5·4	14 7·1
Apr. 2	18·4	4 20·1	10	1·6	12 3·4	16	8·9	18 10·6
6	21·9	8 23·6	14	5·1	16 6·8	20	12·3	22 14·1

Titania.

	h			h		h			h
Mar. 1	4·1	S.	Apr. 4	23·9	May 9	19·9	S.	June 13	15·8
3	8·3	sup.	7	4·2	12	0·1	sup.	15	20·1
5	12·5	N.	9	8·4	14	4·4	N.	18	0·3
7	16·8	inf.	11	12·7	16	8·6	inf.	20	4·5
9	21·0	S.	13	16·9	18	12·9	S.	22	8·8
12	1·3	sup.	15	21·2	20	17·1	sup.	24	13·0
14	5·5	N.	18	1·4	22	21·4	N.	26	17·3
16	9·7	inf.	20	5·7	25	1·6	inf.	28	21·5
18	14·0	S.	22	9·9	27	5·9	S.	July 1	1·7
20	18·2	sup.	24	14·2	29	10·1	sup.	3	6·0
22	22·5	N.	26	18·4	31	14·4	N.	5	10·2
25	2·7	inf.	28	22·7	June 2	18·6	inf.	7	14·5
27	7·0	S.	May 1	2·9	4	22·8	S.	9	18·7
29	11·2	sup.	3	7·2	7	3·1	sup.	11	22·9
31	15·5	N.	5	11·4	9	7·3	N.	14	3·2
Apr. 2	19·7	inf.	7	15·6	11	11·6	inf.	16	7·4

Oberon.

	h			h		h			h
Mar. 1	6·4	N.	Apr. 10	16·0	May 21	1·7	N.	June 30	11·2
4	15·2	inf.	14	0·9	24	10·5	inf.	July 3	20·0
8	0·0	S.	17	9·7	27	19·3	S.	7	4·8
11	8·8	sup.	20	18·5	31	4·1	sup.	10	13·6
14	17·6	N.	24	3·3	June 3	12·9	N.	13	22·4
18	2·4	inf.	27	12·1	6	21·7	inf.	17	7·1
21	11·2	S.	30	20·9	10	6·5	S.		
24	20·0	sup.	May 4	5·9	13	15·3	sup.		
28	4·8	N.	7	14·5	17	0·9	N.		
31	13·6	inf.	10	23·3	20	8·9	inf.		
Apr. 3	22·4	S.	14	8·1	23	17·7	S.		
7	7·2	sup.	17	16·9	27	2·5	sup.		

Titania and *Oberon* will appear in opposite directions from the centre of the planet :—

	h		h		h
Feb. 28	23·7	Apr. 19	6·3	June 7	12·9
Mar. 25	15·0	May 13	21·6	July 2	4·3

and in the same direction :—

	h		h		h
Mar. 13	7·3	May 1	13·9	June 19	20·6
Apr. 6	22·6	26	5·2	July 14	11·9

Ephemeris for Physical Observations of Mars, 1890. By A. Marth.

Greenwich Noon.	Angle of Position of ♂'s Axis.	Areographical Longit. of Centre	Areographical Latit. of Disc.	Apparent Diameter.	ϱ	Q	E	Light-ratio.
1890.	°	°	°	″	″	°	°	
Feb. 25	36·58	183·03	+10·19	8·24	0·85	282·53	37·39	0·170
27	36·43	164·04	9·85	8·38	·86	282·20	37·32	·177
Mar. 1	36·28	145·07	+9·52	8·53	·87	281·88	37·24	0·184
3	36·13	126·12	9·20	8·69	·88	281·56	37·14	·191
5	35·97	107·18	8·88	8·85	·89	281·25	37·02	·199
7	35·81	88·26	8·57	9·02	·90	280·94	36·87	·207
9	35·64	69·36	8·27	9·19	·91	280·63	36·71	·216
11	35·48	50·48	7·98	9·37	·92	280·33	36·52	·225
13	35·31	31·62	7·69	9·56	·93	280·04	36·31	·235
15	35·14	12·77	7·41	9·75	·93	279·76	36·07	·246
17	34·97	353·95	7·15	9·94	·94	279·48	35·81	·257
19	34·80	335·15	6·90	10·14	·94	279·21	35·52	·269
21	34·64	316·38	6·65	10·35	·95	278·96	35·20	·281
23	34·48	297·63	6·42	10·56	·95	278·71	34·85	·294
25	34·32	278·90	6·21	10·78	·95	278·48	34·47	·308
27	34·17	260·20	6·01	11·01	·94	278·26	34·06	·323
29	34·02	241·52	5·82	11·24	·94	278·05	33·62	·338
31	33·88	222·88	5·65	11·48	·93	277·85	33·14	·355
Apr. 2	33·74	204·26	+5·49	11·73	·92	277·67	32·62	0·372
4	33·62	185·67	5·35	11·98	·91	277·51	32·07	·391
6	33·50	167·11	5·22	12·24	·90	277·37	31·48	·410
8	33·40	148·58	5·12	12·51	·89	277·25	30·85	·431
10	33·30	130·09	5·04	12·78	·87	277·15	30·18	·453
12	33·22	111·63	4·97	13·06	·85	277·07	29·46	·476
14	33·15	93·21	4·93	13·35	·82	277·01	28·70	·500
16	33·10	74·83	4·91	13·64	·79	276·98	27·89	·526
18	33·06	56·49	4·91	13·94	·76	276·98	27·03	·553
20	33·04	38·19	4·93	14·24	·73	277·01	26·12	·581
22	33·03	19·92	4·98	14·54	·69	277·08	25·16	·610
24	33·04	1·70	5·05	14·85	·65	277·18	24·15	·641
26	33·06	343·52	5·15	15·15	·61	277·31	23·09	·672
28	33·10	325·38	5·27	15·46	·56	277·49	21·97	·705
30	33·16	307·29	5·42	15·77	·51	277·72	20·80	·739
May 2	33·24	289·24	+5·59	16·08	·46	278·00	19·57	0·773
4	33·33	271·23	5·78	16·38	·41	278·34	18·29	·808

Greenwich Noon.	Angle of Position of ♂'s Axis.	Areographical Longit. of Centre	Areographical Latit. of Disc.	Apparent Diameter.	q	Q	E	Light-ratio.
1890.	°	°	°	″	″	°	°	
May 6	33·44	253·27	+6·00	16·68	·36	278·76	16·96	0·844
8	33·56	235·35	6·25	16·97	·31	279·26	15·58	·880
10	33·70	217·47	6·51	17·25	·26	279·87	14·15	·915
12	33·85	199·62	6·80	17·53	·21	280·63	12·67	·950
14	34·01	181·82	7·11	17·79	·17	281·57	11·14	0·985
16	34·18	164·05	7·44	18·03	·13	282·80	9·57	1·018
18	34·37	146·32	7·79	18·26	·09	284·48	7·96	1·050
20	34·56	128·62	8·15	18·47	·06	286·94	6·33	1·080
22	34·76	110·94	8·52	18·66	·03	291·0	4·68	1·107
24	34·96	93·28	8·90	18·82	·01	299·3	3·05	1·132
26	35·16	75·63	9·28	18·96	·00	324·3	1·59	1·154
28	35·35	58·00	9·67	19·08	·00	37·6	1·34	1·172
30	35·55	40·37	10·06	19·17	·01	72·4	2·69	1·187
June 1	35·74	22·74	+10·45	19·24	·03	82·8	4·35	1·198
3	35·92	5·11	10·83	19·27	·05	87·62	6·06	1·205
5	36·10	347·47	11·20	19·28	·09	90·41	7·78	1·209
7	36·27	329·81	11·56	19·27	·13	92·30	9·50	1·208
9	36·42	312·14	11·90	19·23	·18	93·70	11·21	1·204
11	36·57	294·44	12·22	19·16	·24	94·79	12·89	1·196
13	36·70	276·70	12·53	19·07	·31	95·68	14·55	1·185
15	36·82	258·93	12·82	18·96	·38	96·43	16·17	1·171
17	36·93	241·13	13·08	18·83	·45	97·07	17·75	1·154
19	37·03	223·29	13·32	18·68	·52	97·62	19·29	1·134
21	37·12	205·40	13·54	18·51	·60	98·11	20·79	1·112
23	37·19	187·46	13·73	18·33	·68	98·54	22·24	1·088
25	37·25	169·48	13·89	18·13	·76	98·91	23·64	1·064
27	37·30	151·44	14·02	17·93	·84	99·24	24·98	1·039
29	37·34	133·35	14·13	17·71	·92	99·53	26·28	1·012
July 1	37·37	115·21	+14·21	17·49	0·99	99·78	27·52	0·985
3	37·38	97·02	14·27	17·26	1·06	99·99	28·71	·958
5	37·39	78·78	14·30	17·03	1·13	100·17	29·85	·930
7	37·39	60·48	14·30	16·79	1·19	100·32	30·94	·903
9	37·37	42·14	14·28	16·55	1·25	100·44	31·97	·876
11	37·35	23·75	14·23	16·31	1·31	100·53	32·96	·849
13	37·31	5·31	14·16	16·07	1·37	100·60	33·90	·823
15	37·27	346·82	14·06	15·83	1·42	100·64	34·79	·797
17	37·21	328·29	13·94	15·59	1·46	100·65	35·64	·772
19	37·14	309·71	13·80	15·36	1·50	100·64	36·44	·748

Greenwich Noon.	Angle of Position of ♂'s Axis.	Areographical Longit. of Centre	Areographical Latit. of Disc.	Apparent Diameter.	q	Q	E	Light-ratio.
1890.	°	°	°	″	″	°	°	
July 21	37·06	291·09	+13·63	15·12	1·54	100·61	37·20	0·724
23	36·97	272·43	13·44	14·89	1·57	100·55	37·91	·701
25	36·87	253·72	13·23	14·66	1·60	100·47	38·58	·679
27	36·75	234·98	13·01	14·44	1·63	100·37	39·22	·658
29	36·62	216·20	12·76	14·22	1·65	100·25	39·82	·638
31	36·48	197·39	12·49	14·00	1·67	100·10	40·39	·618
Aug. 2	36·32	178·55	+12·21	13·79	1·69	99·93	40·92	0·599
4	36·15	159·67	11·91	13·58	1·70	99·75	41·41	·581
6	35·96	140·76	11·59	13·38	1·71	99·55	41·88	·563
8	35·76	121·82	11·25	13·18	1·72	99·33	42·31	·546
10	35·54	102·85	10·90	12·98	1·72	99·09	42·71	·530
12	35·31	83·86	10·53	12·79	1·73	98·83	43·09	·515
14	35·06	64·84	10·15	12·61	1·73	98·56	43·44	·500
16	34·80	45·80	9·75	12·42	1·73	98·27	43·77	·486
18	34·51	26·74	9·34	12·24	1·72	97·96	44·07	·472
20	34·21	7·65	8·91	12·07	1·72	97·64	44·35	·459
22	33·89	348·54	8·17	11·90	1·71	97·30	44·60	·446
24	33·55	329·41	8·02	11·74	1·71	96·94	44·83	·434
26	33·19	310·26	7·56	11·58	1·70	96·56	45·05	·422
28	32·82	291·10	7·08	11·42	1·69	96·18	45·24	·411
30	32·43	271·91	6·59	11·26	1·68	95·78	45·41	·400
Sept. 1	32·02	252·71	+6·10	11·11	1·67	95·37	45·57	0·390
3	31·59	233·49	5·59	10·96	1·66	94·95	45·71	·380
5	31·15	214·26	5·07	10·82	1·64	94·51	45·84	·371
7	30·69	195·01	4·54	10·68	1·63	94·06	45·95	·362
9	30·20	175·75	4·01	10·54	1·61	93·60	46·04	·353
11	29·69	156·48	3·47	10·41	1·60	93·12	46·12	·344
13	29·17	137·19	2·92	10·28	1·58	92·64	46·18	·336
15	28·63	117·89	2·36	10·15	1·56	92·15	46·23	·328
17	28·07	98·57	1·79	10·02	1·55	91·65	46·26	·320
19	27·50	79·24	1·22	9·90	1·53	91·14	46·28	·312
21	26·91	59·89	0·64	9·78	1·51	90·62	46·29	·305
23	26·30	40·54	+0·06	9·66	1·49	90·09	46·29	·298
25	25·67	21·17	−0·53	9·54	1·47	89·56	46·28	·292
27	25·03	1·79	1·12	9·43	1·46	89·02	46·26	·285
29	24·37	342·41	1·72	9·32	1·44	88·48	46·23	·279
Oct. 1	23·69	323·01	−2·32	9·21	1·42	87·93	46·18	0·273
3	23·00	303·59	2·93	9·11	1·40	87·38	46·13	·267

Greenwich Noon.	Angle of Position of ♂'s Axis.	Areographical Longit. of Centre	Areographical Latit. of Disc.	Apparent Diameter.	q	Q	E	Light-ratio.
1890.	°	°	°	″	″	°	°	
Oct. 5	22·30	284·17	−3·53	9·00	1·38	86·82	46·07	0·261
7	21·58	264·74	4·14	8·90	1·36	86·27	46·00	·255
9	20·85	245·30	4·75	8·80	1·34	85·71	45·92	·250
11	20·10	225·84	5·36	8·70	1·32	85·15	45·83	·245
13	19·34	206·37	5·97	8·61	1·30	84·59	45·73	·240
15	18·57	186·89	6·59	8·51	1·28	84·02	45·63	·235
17	17·78	167·40	7·20	8·42	1·26	83·46	45·51	·230
19	16·99	147·90	7·81	8·33	1·24	82·91	45·39	·225
21	16·18	128·39	8·42	8·24	1·22	82·35	45·26	·220
23	15·37	108·87	9·02	8·15	1·20	81·80	45·13	·216
25	14·54	89·34	9·63	8·06	1·18	81·25	44·99	·211
27	13·71	69·79	10·23	7·98	1·16	80·70	44·84	·207
29	12·86	50·23	10·82	7·89	1·14	80·16	44·69	·203
31	12·01	30·67	−11·41	7·81	1·12	79·63	44·53	0·199

Q denotes the position-angle, and q the amount of the greatest defect of illumination, E the areocentric angle between Earth and Sun. The last column gives the ratio of the apparent brightness of *Mars* to that at mean opposition, the diminution of brightness due to the phase being assumed to depend simply on the proportion of the unilluminated portion to the whole of the disc.

The data of the ephemeris are founded upon the same elements as those for the oppositions of 1886 and 1888, and are to be interpolated directly for the times for which they are required, the equation of light having already been taken into account. The differences of successive values of the areographical longitude of the centre amount to one rotation and some 340 degrees, so that the greatest difference, at the end of May, is 702°·37, and the smallest, at the end of October, 700°·44.

The adopted zero-meridian will apparently pass the centre of the disc of *Mars* at the following Greenwich mean times:—

	h	m		h	m		h	m
Feb. 25	12	7·1	Mar. 6	17	57·4	Mar. 15	23	46·2
26	12	46·1	7	18	36·3	17	0	24·9
27	13	25·1	8	19	15·1	18	1	3·5
28	14	4·0	9	19	53·9	19	1	42·1
Mar. 1	14	43·0	10	20	32·7	20	2	20·6
2	15	21·9	11	21	11·4	21	2	59·2
3	16	0·8	12	21	50·1	22	3	37·7
4	16	39·7	13	22	28·8	23	4	16·2
5	17	18·6	14	23	7·5	24	4	54·6

	h	m		h	m		h	m
Mar. 25	5	33·1	May 5	6	41·0	June 15	6	54·5
26	6	11·5	6	7	17·8	16	7	31·0
27	6	49·9	7	7	54·6	17	8	7·5
28	7	28·2	8	8	31·3	18	8	44·1
29	8	6·5	9	9	8·0	19	9	20·8
30	8	44·8	10	9	44·6	20	9	57·5
31	9	23·1	11	10	21·2	21	10	34·2
Apr. 1	10	1·3	12	10	57·8	22	11	11·0
2	10	39·5	13	11	34·3	23	11	47·8
3	11	17·7	14	12	10·8	24	12	24·7
4	11	55·8	15	12	47·2	25	13	1·6
5	12	33·9	16	13	23·6	26	13	38·6
6	13	12·0	17	14	0·0	27	14	15·7
7	13	50·0	18	14	36·3	28	14	52·8
8	14	28·0	19	15	12·6	29	15	30·0
9	15	5·9	20	15	48·8	30	16	7·2
10	15	43·8	21	16	25·1	July 1	16	44·5
11	16	21·7	22	17	1·3	2	17	21·9
12	16	59·6	23	17	37·5	3	17	59·3
13	17	37·4	24	18	13·7	4	18	36·7
14	18	15·1	25	18	49·9	5	19	14·2
15	18	52·8	26	19	26·0	6	19	51·8
16	19	30·5	27	20	2·2	7	20	29·4
17	20	8·1	28	20	38·3	8	21	7·0
18	20	45·7	29	21	14·5	9	21	44·7
19	21	23·3	30	22	50·6	10	22	22·5
20	22	0·8	31	22	26·8	11	23	0·3
21	22	38·3	June 1	23	2·9	12	23	38·2
22	23	15·7	2	23	39·0	14	0	16·1
23	23	53·0	4	0	15·2	15	0	54·1
25	0	30·3	5	0	51·4	16	1	32·1
26	1	7·6	6	1	27·6	17	2	10·2
27	1	44·8	7	2	3·8	18	2	48·3
28	2	22·0	8	2	40·0	19	3	26·5
29	2	59·2	9	3	16·3	20	4	4·7
30	3	36·3	10	3	52·6	21	4	43·0
May 1	4	13·3	11	4	28·9	22	5	21·3
2	4	50·3	12	5	5·2	23	5	59·6
3	5	27·3	13	5	41·6	24	6	38·0
4	6	4·2	14	6	18·0	25	7	16·4

	h	m		h	m		h	m
July 26	7	54·9	Aug. 28	4	43·2	Sept. 30	1	52·2
27	8	33·4	29	5	22·6	Oct. 1	2	32·1
28	9	12·0	30	6	2·0	2	3	12·0
29	9	50·6	31	6	41·4	3	3	51·9
30	10	29·2	Sept. 1	7	20·9	4	4	31·8
31	11	7·9	2	8	0·4	5	5	11·7
Aug. 1	11	46·6	3	8	39·9	6	5	51·7
2	12	25·3	4	9	19·4	7	6	31·6
3	13	4·1	5	9	59·0	8	7	11·6
4	13	42·9	6	10	38·5	9	7	51·6
5	14	21·7	7	11	18·1	10	8	31·6
6	15	0·6	8	11	57·7	11	9	11·6
7	15	39·5	9	12	37·3	12	9	51·6
8	16	18·5	10	13	16·9	13	10	31·6
9	16	57·5	11	13	56·5	14	11	11·6
10	17	36·5	12	14	36·1	15	11	51·7
11	18	15·5	13	15	15·8	16	12	31·8
12	18	54·5	14	15	55·5	17	13	11·8
13	19	33·6	15	16	35·2	18	13	51·9
14	20	12·7	16	17	14·9	19	14	32·0
15	20	51·8	17	17	54·6	20	15	12·1
16	21	30·9	18	18	34·3	21	15	52·2
17	22	10·1	19	19	14·0	22	16	32·4
18	22	49·3	20	19	53·8	23	17	12·5
19	23	28·6	21	20	33·6	24	17	52·7
21	0	7·8	22	21	13·4	25	18	32·0
22	0	47·1	23	21	53·2	26	19	13·0
23	1	26·4	24	22	33·0	27	19	53·0
24	2	5·7	25	23	12·8	28	20	33·5
25	2	45·0	26	23	52·6	29	21	13·7
26	3	24·4	28	0	32·5	30	21	53·9
27	4	3·8	29	1	12·3	31	22	34·1

Ephemeris of the Satellites of Mars, 1890. By A. Marth.

Greenwich Noon.		*Phobos.*				*Deimos.*				
	P	a_1	b_1	u_1-U	a_2	b_2	u_2-U	U	B
1890.	°	″	″	°	″	″	°	°	°
Apr. 14	33·29	18·45	+1·85	343·23	46·19	+4·65	234·09	210·09	+5·78
16	33·24	18·86	1·89	80·81	47·19	4·73	84·24	210·29	5·76
18	33·20	19·27	1·93	178·44	48·21	4·84	294·43	210·45	5·76
20	33·18	19·68	1·98	276·11	49·25	4·96	144·66	210·57	5·78
22	33·17	20·10	2·04	13·81	50·30	5·11	354·94	210·64	5·83
24	33·18	20·52	2·11	111·55	51·36	5·28	205·25	210·67	5·90
26	33·20	20·95	2·19	209·33	52·43	5·48	55·61	210·66	6·00
28	33·24	21·38	2·28	307·15	53·50	5·71	266·01	210·61	6·12
30	33·30	21·80	2·38	45·02	54·56	5·96	116·45	210·51	6·27
May 2	33·37	22·23	+2·49	142·93	55·62	+6·24	326·93	210·37	+6·44
4	33·46	22·65	2·62	240·87	56·67	6·55	177·46	210·18	6·63
6	33·56	23·06	2·76	338·85	57·71	6·89	28·03	209·95	6·85
8	33·68	23·46	2·90	76·88	58·72	7·26	238·65	209·67	7·10
10	33·81	23·85	3·06	174·95	59·70	7·66	89·31	209·36	7·37
12	33·96	24·23	3·23	273·05	60·64	8·08	300·00	209·00	7·66
14	34·12	24·59	3·41	11·19	61·54	8·53	150·74	208·60	7·97
16	34·29	24·93	3·60	109·36	62·39	9·00	1·51	208·17	8·30
18	34·47	25·25	3·80	207·56	63·18	9·49	212·31	207·70	8·64
20	34·65	25·54	4·00	305·79	63·90	10·00	63·14	207·20	9·00
22	34·84	25·80	4·20	44·04	64·55	10·52	274·00	206·68	9·38
24	35·03	26·03	4·41	142·30	65·13	11·04	124·88	206·13	9·76
26	35·22	26·22	4·62	240·58	65·62	11·56	335·78	205·56	10·14
28	35·41	26·38	4·82	338·86	66·02	12·07	186·69	204·98	10·53
30	35·60	26·51	5·02	77·15	66·33	12·57	37·60	204·40	10·92
June 1	35·78	26·60	+5·21	175·44	66·55	+13·05	248·51	203·81	+11·31
3	35·95	26·65	5·40	273·72	66·68	13·51	99·42	203·23	11·69
5	36·12	26·66	5·57	11·98	66·72	13·94	310·32	202·65	12·06
7	36·28	26·64	5·73	110·23	66·67	14·33	161·21	202·09	12·42
9	36·43	26·58	5·87	208·45	66·53	14·69	12·07	201·55	12·76
11	36·57	26·49	6·00	306·65	66·30	15·01	222·91	201·03	13·09
13	36·69	26·37	6·11	44·82	65·99	15·29	73·72	200·54	13·39
15	36·81	26·21	6·20	142·94	65·60	15·52	284·50	200·08	13·68
17	36·91	26·03	6·27	241·03	65·14	15·70	135·24	199·66	13·95
19	37·00	25·82	6·33	339·07	64·62	15·84	345·94	199·28	14·19
21	37·08	25·59	6·36	77·07	64·04	15·93	196·59	198·94	14·40

Greenwich Noon.	P	*Phobos.* a_1	b_1	u_1-U	*Deimos.* a_2	b_2	u_2-U	U	B
1890.	°	″	″	°	″	″	°	°	°
June 23	37·15	25·34	+6·38	175·02	63·41	+15·97	47·19	198·65	+14·59
25	37·21	25·07	6·38	272·91	62·74	15·97	257·75	198·41	14·75
27	37·25	24·79	6·37	10·75	62·03	15·93	108·26	198·22	14·88
29	37·29	24·49	6·34	108·54	61·28	15·85	318·71	198·08	14·99
July 1	37·32	24·18	+6·29	206·28	60·51	+15·74	169·12	197·99	+15·07
3	37·33	23·86	6·23	303·96	59·72	15·59	19·47	197·95	15·13
5	37·34	23·54	6·16	41·59	58·91	15·40	229·77	197·96	15·16
7	37·34	23·21	6·07	139·17	58·09	15·19	80·02	198·02	15·16
9	37·32	22·88	5·97	236·70	57·27	14·95	290·22	198·13	15·14
11	37·30	22·55	5·87	334·17	56·44	14·69	140·37	198·29	15·09
13	37·27	22·22	5·76	71·59	55·61	14·41	350·47	198·50	15·02
15	37·23	21·89	5·64	168·97	54·78	14·10	200·53	198·76	14·92
17	37·18	21·56	+5·51	266·30	53·95	+13·78	50·54	199·06	+14·80
19	37·11	21·23	5·37	3·58	53·13	13·44	260·50	199·40	14·66
21	37·03	20·91	5·23	100·82	52·32	13·09	110·42	199·79	14·49
23	36·95	20·59	5·09	198·02	51·52	12·73	320·30	200·22	14·30
25	36·86	20·27	4·94	295·18	50·73	12·35	170·14	200·69	14·10
27	36·75	19·96	4·78	32·29	49·95	11·97	19·94	201·20	13·87
29	36·63	19·66	4·63	129·37	49·19	11·58	229·70	201·74	13·62
31	36·49	19·36	4·47	226·42	48·45	11·19	79·43	202·32	13·35
Aug. 2	36·34	19·07	+4·31	323·43	47·71	+10·79	288·13	202·93	+13·07
4	36·18	18·78	4·15	60·40	46·99	10·39	138·79	203·58	12·77
6	36·01	18·50	3·99	157·35	46·29	9·98	348·42	203·25	12·45
8	35·82	18·22	3·82	254·27	45·60	9·57	198·03	204·95	12·11
10	35·61	17·95	3·66	351·16	44·92	9·16	47·61	205·68	11·76
12	35·39	17·69	3·49	88·02	44·26	8·74	257·16	206·44	11·39
14	35·15	17·43	3·33	184·86	43·61	8·33	106·69	207·22	11·01
16	34·90	17·18	+3·16	281·67	42·98	+7·91	316·19	208·02	+10·61

In this ephemeris the two satellites are assumed to move in a plane, the node N and inclination J of which, in reference to the plane parallel to the Earth's equator, are :—

$$N = 49°·563\,; \quad J = 36°·021.$$

The assumed orbital longitudes, reckoned from the node, are :—

$$\text{Phobos } u_1 = 22°·41 + 1128°·8445\ (t - t_0)$$
$$\text{Deimos } u_2 = 93·12 + 285·1622\ (t - t_0)$$

the epoch t_0 being 1890, June, 1·0 Gr.

The values of P, a, b, $u-U$ are to be interpolated directly for the times for which the positions of the satellites are required, and the position-angles p and distances s are then found by means of the formulæ:—

$$s \sin (p-P) = a \sin (u-U)$$
$$s \cos (p-P) = b \cos (u-U).$$

Greenwich times, at which the satellites will be at their greatest elongations (e in position P+90° and w in position P−90°), the designation, in the case of *Phobos*, belonging to both given times, so that an elongation on the opposite side occurs at mid-time between them:—

1890.	*Phobos.*		*Deimos.*	1890.	*Phobos.*		*Deimos.*
	h		h		h		h
Apr. 14	17·6	*e*	25·2 18·2 *e*	May 12	11·4	*e*	19·1 12·6 *e*
15	16·5	*e*	24·2 24·5 *e*	13	14·2	*w*	21·8 18·9 *e*
16	15·5	*e*	23·2 15·6 *w*	14	13·2	*w*	20·8 10·0 *w*
17	14·5	*e*	22·1 21·9 *w*	15	12·1	*w*	19·8 16·3 *w*
18	13·4	*e*	21·1 13·1 *e*	16	11·1	*w*	18·7 22·6 *w*
19	12·4	*e*	20·0 19·4 *e*	17	13·8	*e*	21·5 13·7 *e*
20	15·2	*w*	22·8 25·7 *e*	18	12·8	*e*	20·5 20·0 *e*
21	14·1	*w*	21·8 16·8 *w*	19	11·8	*e*	19·4 11·1 *w*
22	13·1	*w*	20·8 23·1 *w*	20	10·7	*e*	18·4 17·4 *w*
23	15·9	*e*	23·5 14·3 *e*	21	13·5	*w*	21·1 23·7 *w*
24	14·9	*e*	22·5 20·6 *e*	22	12·5	*w*	20·1 15·3 *e*
25	13·8	*e*	21·5 11·7 *w*	23	11·4	*w*	19·1 21·1 *e*
26	12·8	*e*	20·4 18·0 *w*	24	10·4	*w*	18·0 12·2 *w*
27	11·7	*e*	19·4 24·3 *w*	25	13·1	*e*	20·8 18·5 *w*
28	14·5	*w*	22·2 15·5 *e*	26	12·1	*e*	19·7 9·6 *e*
29	13·5	*w*	21·1 21·8 *e*	27	11·1	*e*	18·7 15·9 *e*
30	12·4	*w*	20·1 12·9 *w*	28	10·0	*e*	17·7 22·1 *e*
May 1	15·2	*e*	22·9 19·2 *w*	29	12·8	*w*	20·4 13·3 *w*
2	14·2	*e*	21·8 10·3 *e*	30	11·7	*w*	19·4 19·5 *w*
3	13·1	*e*	20·8 16·6 *e*	31	10·7	*w*	18·4 10·7 *e*
4	12·1	*e*	19·7 22·9 *e*	June 1	9·7	*w*	17·3 16·9 *e*
5	14·9	*w*	22·5 14·1 *w*	2	12·4	*e*	20·1 8·1 *w*
6	13·8	*w*	21·5 20·3 *w*	3	11·4	*e*	19·0 14·3 *w*
7	12·8	*w*	20·4 11·5 *e*	4	10·3	*e*	18·0 20·6 *w*
8	11·7	*w*	19·4 17·8 *e*	5	9·3	*e*	17·0 11·7 *e*
9	14·5	*e*	22·2 8·9 *w*	6	12·1	*w*	19·7 18·0 *e*
10	13·5	*e*	21·1 15·2 *w*	7	11·0	*w*	18·7 9·1 *w*
11	12·4	*e*	20·1 21·5 *w*	8	10·0	*w*	17·6 15·4 *w*

1890.	*Phobos.*			*Deimos.*		1890.	*Phobos.*			*Deimos.*	
	h		h	h			h		h	h	
June 9	12·8	*e*	20·4	21·7	*w*	July 11	10·1	*e*	17·8	10·9	*w*
10	11·7	*e*	19·4	12·8	*e*	12	9·1	*e*	16·7	17·2	*w*
11	10·7	*e*	18·3	19·1	*e*	13	8·0	*e*	15·7	8·4	*e*
12	9·6	*e*	17·3	10·2	*w*	14	10·8	*w*	18·5	14·7	*e*
13	12·4	*w*	20·1	16·5	*w*	15	9·8	*w*	17·5	5·8	*w*
14	11·4	*w*	19·0	7·6	*e*	16	8·8	*w*	16·4	12·2	*w*
15	10·4	*w*	18·0	13·9	*e*	17	11·6	*e*	19·2	18·5	*w*
16	9·3	*w*	17·0	20·2	*e*	18	10·5	*e*	18·2	9·6	*e*
17	8·3	*w*	15·9	11·3	*w*	19	9·5	*e*	17·1	16·0	*e*
18	11·1	*e*	18·7	17·6	*w*	20	8·5	*e*	16·1	7·1	*w*
19	10·0	*e*	17·7	8·7	*e*	21	7·4	*e*	15·1	13·4	*w*
20	9·0	*e*	16·6	15·0	*e*	22	10·2	*w*	17·9	19·8	*w*
21	11·7	*w*	19·4	21·3	*e*	23	9·2	*w*	16·8	10·9	*e*
22	10·7	*w*	18·4	12·5	*w*	24	8·1	*w*	15·8	17·2	*e*
23	9·7	*w*	17·3	18·7	*w*	25	7·1	*w*	14·8	8·4	*w*
24	8·6	*w*	16·3	9·9	*e*	26	9·9	*e*	17·6	14·7	*w*
25	11·4	*e*	19·1	16·2	*e*	27	8·9	*e*	16·5	5·9	*e*
26	10·4	*e*	18·0	7·3	*w*	28	7·8	*e*	15·5	12·2	*e*
27	9·3	*e*	17·0	13·6	*w*	29	10·6	*w*	18·3	18·6	*e*
28	8·3	*e*	15·9	19·9	*w*	30	9·6	*w*	17·3	9·7	*w*
29	11·1	*w*	18·7	11·0	*e*	31	8·6	*w*	16·2	16·1	*w*
30	10·0	*w*	17·7	17·3	*e*	Aug. 1	7·5	*w*	15·2	7·2	*e*
July 1	9·0	*w*	16·7	8·5	*w*	2	10·3	*e*	18·0	13·6	*e*
2	8·0	*w*	15·6	14·8	*w*	3	9·3	*e*	17·0	19·9	*e*
3	10·8	*e*	18·4	5·9	*e*	4	8·3	*e*	15·9	11·1	*w*
4	9·7	*e*	17·4	12·2	*e*	5	7·3	*e*	14·9	17·4	*w*
5	8·7	*e*	16·3	18·5	*e*	6	10·0	*w*	17·7	8·6	*e*
6	11·5	*w*	19·1	9·7	*w*	7	9·0	*w*	16·7	14·9	*e*
7	10·4	*w*	18·1	16·0	*w*	8	8·0	*w*	15·6	6·1	*w*
8	9·4	*w*	17·0	7·1	*e*	9	7·0	*w*	14·6	12·4	*w*
9	8·4	*w*	16·0	13·4	*e*	10	9·8	*e*	17·4	18·7	*w*
10	11·2	*e*	18·8	19·8	*e*	11	8·7	*e*	16·4	9·9	*e*

If the assumed plane of the orbits does not differ too much from their true planes, this year's cycle of eclipses of *Phobos* will last from about March 19 to October 9, that of *Deimos* from June 2 to August 9, the central eclipses occurring about July 7. The earliest eclipses of *Deimos* will not be observable, but a week after the beginning of the cycle the satellite will be at its disappearance more than half a semi-diameter of the planet's disc outside the disc. In order to induce observers to watch duly for the disappearances and reappearances of the satellite, I give

approximate Greenwich times of the middle of the eclipses and of their semi-duration, it being understood that these predictions may be sensibly in error. It will be of special importance to observe the latest eclipses of the cycle, the duration of which is very uncertain.

Eclipses of Deimos.

	Middle.	Semi-dur.		Middle.	Semi-dur.		Middle.	Semi-dur.
	h m	m		h m	m		h m	m
June 8	23 47	24	June 30	11 47	40	July 24	12 31	35
11	12 29	27	July 1	18 8	40	25	18 53	34
12	18 50	29	5	13 12	41	28	7 36	31
15	7 32	32	6	19 33	41	29	13 57	30
16	13 54	33	9	8 16	41	30	20 19	28
17	20 15	34	10	14 37	41	Aug. 2	9 1	24
20	8 57	36	11	20 58	41	3	15 23	22
21	15 18	37	14	9 41	40	7	10 27	? 12
22	21 39	38	15	16 2	40	8	16 49	? 8
25	10 22	39	19	11 6	38	12	11 54	?
26	16 43	39	20	17 27	38	13	18 15	?

The disappearances of *Phobos* into the planet's shadow will not be observable, and I give therefore approximate Greenwich times of its reappearances, the error of which, though it may be very sensible, will probably not vary much.

Eclipses of Phobos. Reappearances.

	h m	h m		h m	h m		h m	h m
June 15	13 0	20 39	July 5	7 46	15 26	July 25	10 11	17 51
16	11 58	19 38	6	14 24	22 4	26	9 10	16 49
17	10 57	18 36	7	13 22	21 2	27	8 8	15 48
18	9 55	17 34	8	12 21	20 0	28	7 6	14 46
19	8 43	16 23	9	11 19	18 58	29	6 4	13 44
20	15 31	23 10	10	10 18	17 57	30	5 3	12 42
21	14 29	22 9	11	9 16	16 55	31	11 40	19 20
22	13 27	21 7	12	8 14	15 54	Aug. 1	10 38	18 18
23	12 26	20 5	13	7 12	14 52	2	9 37	17 16
24	11 24	19 4	14	6 10	13 50	3	8 35	16 15
25	10 23	18 2	15	12 48	20 28	4	7 34	15 13
26	9 22	17 1	16	11 47	19 26	5	6 32	14 11
27	8 21	16 0	17	10 45	18 25	6	5 30	13 9
28	7 19	14 58	18	9 44	17 23	7	12 8	19 47
29	14 6	21 36	19	8 42	16 21	8	11 6	18 46
30	12 55	20 34	20	7 40	15 20	9	10 5	17 44
July 1	11 53	19 32	21	6 38	14 18	10	9 3	16 42
2	10 51	18 30	22	5 37	13 16	11	8 1	15 40
3	9 50	17 29	23	12 15	19 54	12	7 0	14 39
4	8 48	16 28	24	11 13	18 52	13	5 58	13 37

During the period for which these ephemerides of the satellites are given, the light-ratio (to be found in the preceding ephemeris for physical observations of the planet) is at least one half of that at mean opposition. It would not be worth the trouble to extend micrometrical measurements beyond or even up to the limits of this period. But, as it would be of essential service for the determination of the true planes of the orbits (and thereby for the future determination of the ellipticity of the planet) if observations of some of the earliest and latest eclipses of all cycles, which render such observations feasible, were secured, I venture to give the necessary predictions for the earliest eclipses of *Phobos*, though the light-ratio is only about a quarter of that at mean opposition, and though it is doubtful whether the apparent nearness of the satellite to the limb of the planet at its reappearances from the shadow will not prevent its being seen. The oppositions of *Phobos* to the Sun occur about the following Greenwich times:—

	h m	h m		h m	h m		h m	h m
Mar. 16	14 20	21 59	Mar. 20	17 52	25 31	Mar. 24	13 45	21 24
17	13 18	20 57	21	16 50	24 29	25	20 22	...
18	12 16	19 56	22	15 48	23 27	26	19 21	...
19	18 54	...	23	14 46	22 25	27	18 19	25 58

About $1^h{\cdot}2$ before these times *Phobos* will be at its apparent greatest western elongations. But the apparent positions of both satellites may be found with the help of the following ephemeris, in which the values a, b of the semi-axes of the apparent ellipses are expressed, not in seconds of arc, but in semi-diameters of the planet's disc.

	Phobos.				*Deimos.*		
Greenwich Noon.	P	a_1	b_1	u_1-U	a_2	b_2	u_2-U
	°	"	"	°	"	"	°
Mar. 17	35·06	2·765	+0·391	60·35	6·920	+0·980	175·55
19	34·90		·379	157·55		·949	25·28
21	34·75		·368	254·76		·920	235·04
23	34·60		·357	351·99		·892	84·82
25	34·45	2·765	+0·346	89·25	6·920	+0·866	294·62

If observers will be good enough to publish or communicate in time the results of their endeavours to observe the first eclipses of *Phobos*, I intend to give the prediction for the rest of the cycle, in case that appears desirable.

Note.

Mr. Levander's paper on "The Colours of Stars," on page 33, was printed in abstract; a table, showing the 95 tints observed in the 4984 stars previously mentioned, not being printed.